FULL TITLE
ASP Conference Series, Vol. **VOLUME**, **YEAR OF PUBLICATION**
NAMES OF EDITORS

Optical Monitoring of PKS 2155-304 during August-September 2004 with the KVA telescope

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Abstract. The southern gamma-ray blazar PKS 2155-304 is one of the brightest and most intensively studied prototypes of BL Lac object. PKS 2155-304 has recently aroused the interest of Cherenkov telescope projects like HESS and MAGIC, the former having already observed the source in 2002 and 2003. This blazar was monitored with the KVA optical telescope (R-band intranight photometry and unfiltered polarization observastions), in the frame of a new HESS multiwavelength campaign performed in August-September 2004.

1. Introduction

The southern BL Lac object PKS 2155-304 (z = 0.117) is one of the brightest extragalactic UV and X-ray sources in the sky. This blazar exhibits a complex broadband variability and has been the target of several multiwavelength campaigns and many X-ray satellites like ROSAT, ASCA, RXTE, SAX, Chandra, and XMM (see e.g. Vestrand & Sreekumar 1999; Chiappetti et al. 1999; Brinkmann et al. 2000; Kataoka et al. 2000; Edelson et al. 2001; Tanihata et al. 2001; Zhang et al. 2002; Nicastro et al. 2002; Ciprini 2003; Cagnoni et al. 2004). Fig.1 shows an example of its spectral energy distribution (SED), peaking in the UV-soft-X-ray regime. A continuous X-ray flaring activity, representing the high-energy tail of the synchrotron emission, is typical of this source (Tanihata et al. 2001). PKS 2155-304 was well observed by EGRET in the γ-ray energy range 30 MeV – 10 GeV (see e.g. Urry et al. 1997; Vestrand & Sreekumar 1999), and was also detected by the Cherenkov telescope Mark-6 (Australia) in 1997 (Chadwick et al. 1999). It was not revealed by the same instrument and by the CANGAROO telescope in subsequent years; it was finally detected with high-significance (45σ) by the HESS array of Cherenkov telescopes (Namibia) in 2002–2003 (Aharonian et al. 2005a,b, see Fig.1) and in 2004 (Aharonian et al. in prep). Radio observations (sparse if compared to the optical and high-energy ones) show no strong moving components in VLBI, suggesting low Doppler factors and a mildly relativistic jet on parsec-scale (Piner & Edwards 2004).

2. Optical Observations with the KVA Telescope

Observations of very high energy γ-rays from PKS 2155-304 by Cherenkov telescopes like HESS (`http://www.mpi-hd.mpg.de/hfm/HESS/`) and MAGIC (`http://wwwmagic.mppmu.mpg.de`) simultaneous with optical observations, can provide a noticeable insight into TeV emission processes and help to clarify the differences between blazars peaked at low and high-energy. The recent (1996-

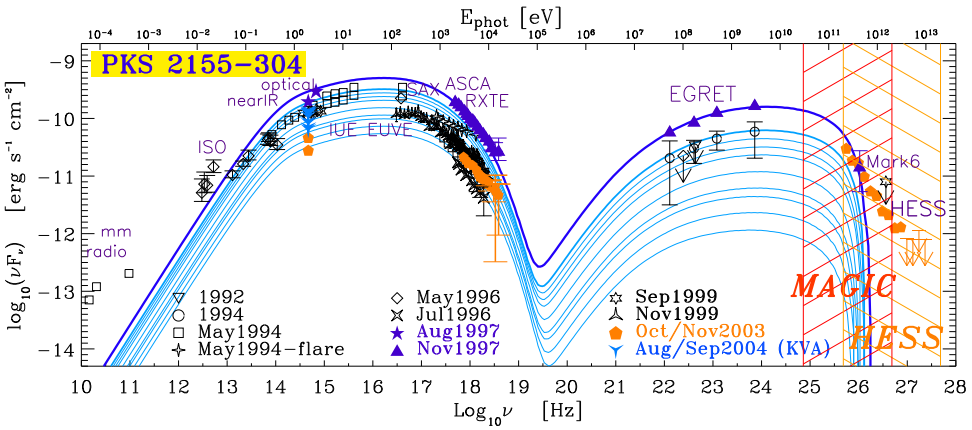

Figure 1. The SED of PKS 2155-304 assembled with observations available around mid-90s (the solid lines are a SSC cooling modelling of Nov.1997 data, Ciprini 2003), and with data from the HESS campaign of Oct.-Nov.2003 (Aharonian et al. 2005b) for comparison. The qualitative sensitivity energy ranges of MAGIC and HESS are superimposed. EGRET energy spectrum has an integral photon index of 1.71 ± 0.24, while the time-averaged photon index measured by HESS in 2002-2003 is 3.32 ± 0.06 (Aharonian et al. 2005a).

2000) optical history of PKS 2155-304 exhibits quiescent phases of mild variability followed by periods of more rapid and stronger activity (day timescales; Dominici et al. 2004), while intranight photo-polarimetric data show a moderate polarization degree (Tommasi et al. 2001). The simultaneous optical and X-ray (RXTE-ASM) emission does not show any correlation (Dominici et al. 2004).

The KVA telescope (Kungliga Vetenskapsakademien, Royal Swedish Academy of Sciences) is located on Roque de los Muchachos, La Palma (Canary Islands), and operated by the Tuorla Observatory, Finland (`http://www.astro.utu.fi`). KVA observations are the main contribution of the Tuorla AGN group to the MAGIC collaboration. MAGIC is a 17m atmospheric imaging Cherenkov telescope (located in the same site), designed to detect cosmic γ-rays with a low-energy threshold ($\sim$40 GeV, see e.g. Lorenz 2004; Cortina 2005). The KVA telescope is composed of a 0.6m f/15 Cassegrain devoted to polarimetry, and a 0.35m f/11 SCT auxiliary telescope for multicolour photometry. KVA is equipped with a polarimeter (superachromatic half-wave retarder, with a calcite plate and a Marconi $1K \times 1K$, 13 μm pixels, thinned back illuminated CCD with high blue sensitivity), and a multiband photometry camera (SBIG ST-8E, $1K \times 1.5K$ CCD, plus filter wheel with $BVRI$ filters). For other instrument details see Berdyugin et al. (2004). This telescope has been successfully operated in remote way (mainly from Finland) through internet connection since autumn 2003. It is controlled by two PCs, incremental encoders and a "Watchdog" software. An IR webcam allows visual checks, a weather station on the mountains keeps track of the observing conditions, and an emergency shutdown procedure is active. KVA is mainly used for optical support observations for MAGIC, long-term monitoring of blazars, and polarimetric surveys. Different types of observations are possible for blazars: a) one R-band photometric point per available night per source; b) a less-sampled but continuous monitoring during the year; c) BVR sequences with polarization data on selected nights. A preview of the data is available at `http://users.utu.fi/kani/1m/`.

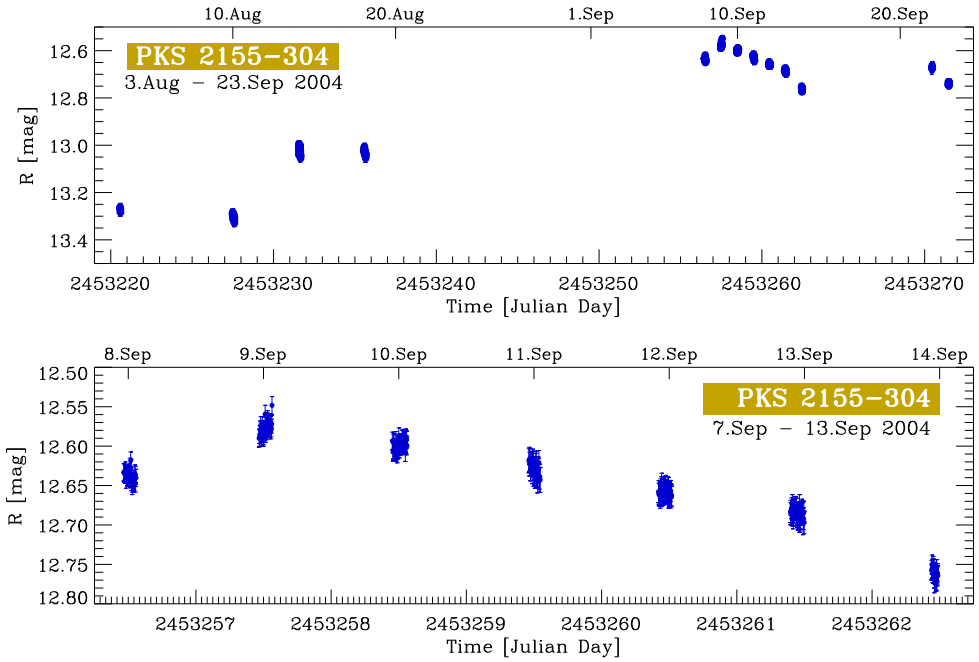

Figure 2. Optical light curve of PKS 2155-304 in R-band obtained with KVA observations from August 3 to September 23, 2004, during a contemporary multiwavelength campaign involving HESS and RXTE. A total of 440 data points were obtained in 13 nights ($\sim$ 38 frames per night on average). The peak of the optical emission is located at JD=2453257.5627 (Sep. 9) with $R = 12.548 \pm 0.012$ mag (unabsorbed flux 31.08 ± 0.32 mJy). The fairly well sampled week around this flare is plotted in the bottom panel.

For the first time, a so low-declination blazar like PKS 2155-304 was observed with the KVA. A total of 440 R-band photometric data points were obtained in 13 nights ($\sim$ 38 frames per night on average) during August 3 – September 23, 2004, in the frame of a multifrequency campaign involving HESS and RXTE. During 4 nights (Sep. 8-9, 9-10, 12 and 22-23) simultaneous polarimetric observations were also performed. The complete optical light curves are presented in Fig.2, and two intranight light curves with polarimetric data are shown in Fig.3. A remarkable optical brightening (up to $R = 12.548 \pm 0.012$ mag) was observed during Sep. 8-10. A preliminary inspection on the 13 intranight light curves does not show any relevant signature of intraday variability, but a more detailed data analysis in under way. Since the galactic latitude of PKS 2155-304 is high ($b = -52.246°$), interstellar polarization along line of sight is negligible. The relatively high level of optical polarization recorded during Sep. 9-10 might provide a signature of the synchrotron nature of this flare.

The KVA observations described above were also a useful preparatory run for the optical follow-up of planned MAGIC observations of PKS 2155-304 at large zenith-angles. MAGIC should be able to derive a proper γ-ray spectrum above 500 GeV for it, and the spectral cutoff due to the extragalactic background light (EBL) absorption, with moderate pointing time and reduced systematic effects (Kranich et al. 2005). PKS 2155-304 represents also an optimal target for simultaneous observations by MAGIC and HESS. In fact possible collaboration

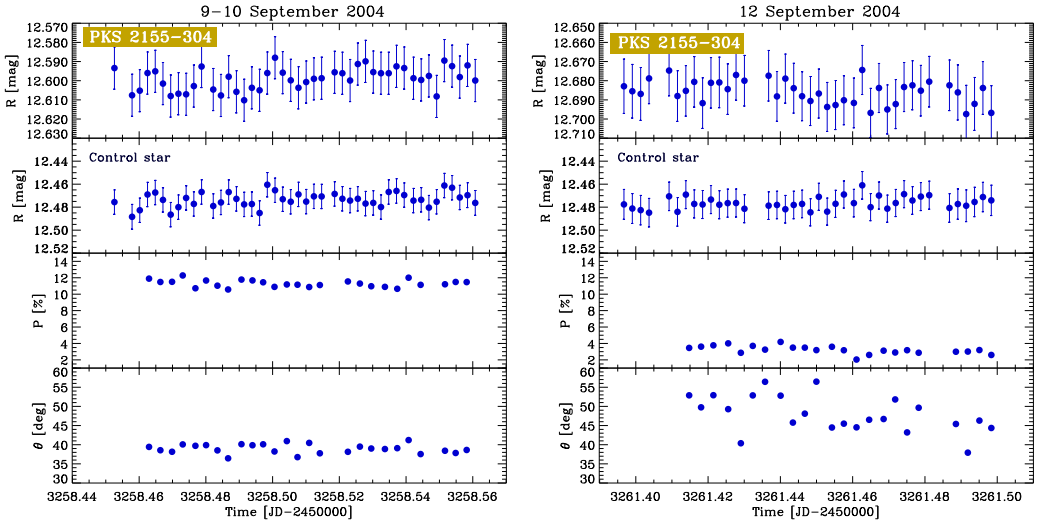

Figure 3. Two intranight light curves of PKS 2155-304 in R-magnitude, and the corresponding unfiltered (white) linear polarization degree and position angle data. A preliminary inspection shows no relevant intraday variability. The decrease of the polarization degree with the flux as like the increase of randomization/variability of the magnetic field direction from Sep. 9-10 to Sep. 12 is clearly visible, suggesting a decay after a non-thermal flare.

observations could provide a larger and well defined energy spectrum of the source, an increased statistics and a cross-calibration of the two detectors.

Acknowledgments. The Tuorla Observatory group, belonging to the Research Training Network ENIGMA, acknowledges European Community funding under contract HPRN-CT-2002-00321. The Tuorla and KVA monitoring programmes have been partially supported by the Academy of Finland.

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